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THE PROCEEDINGS
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THE INSTITUTION OF PRODUCTION ENGINEERS

The Official Journal of the Institution of Production Engineers

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PRODUCTION AND PRODUCTION ENGINEERING TERMINOLOGY.

Terms and their Definitions.

THE Council of the Institution at its meeting on November 28th, 1932, had before it a report from the Development Committee on the subject of "Production and Production Engineering Terminology." The British Committee of the International Management Institute, dealing with the general terminology of rationalisation, had earlier submitted to the Institution provisional definitions of a number of production terms. Some of these were recommended for adoption in the Development Committee's report, but in most cases additions or alterations were put forward.

The Council of the Institution has approved of the following definitions, and authorised their publication to members:

Production Management.—A general term covering the organisation, systematisation, and development of methods of production, commensurate with a pre-determined programme of output.

Production Control.—The collection of data, the transmission of orders, and the progressing of these by individuals appointed for the purpose by the production manager, to see that same are completed by their due dates and in balanced quantities.

Factory Location.—The situation of a factory with respect to its surroundings—climate, railways, ports, housing, motive power, supply of labour and raw materials, markets, etc.

Plant Layout.—The disposition within the factory area of the buildings, and the disposition within the buildings of the machines, stores and assembly sections, etc.

Planning.—Devising and controlling processes of production in such a way that the personnel and facilities of the plant, physical and financial, will be utilised to the best advantage consonant with the degree of accuracy required.

Progress (Progressing).—Arranging for the correct material to be taken to the machines for the performance of processes and the transportation of parts from operation to operation in the various departments through which they have to pass, including the inspection and assembly departments, and ultimate delivery to the despatch department.

Routing.—See **Progress (Progressing).**

Scheduling.—The listing of those parts and the quantities thereof that are required for the completion of a given assembly.

Despatching.—Accepting delivery of finished production from the manufacturing departments and arranging for the re-delivery of these to warehouse or customer.

Flow of Work.—The passage of raw material and partly finished products through the factory as controlled by progress.

Flow-work.—Work passing along a line of machines placed in the correct sequence for the performance of a series of processes required to convert the raw material into a finished component, sometimes moved from machine to machine by mechanical means such as a conveyor.

Line Production.—See **Flow-work.**

Material Handling.—Internal transportation within the factory of raw materials, partially completed parts or of the completed product, within or between departments.

Conveyor.—A mechanically operated means of material handling from point to point along a predetermined route.

Transporter.—Any device, tracked or trackless, used for the movement of material or goods from any one position to any other within the precincts of the factory.

Plant Maintenance.—A term referring to all those functions which are necessary for maintaining both works and machinery in proper running condition.

Production Engineer.—An engineer qualified to hold in an engineering works a position of authority involving responsibility for any technical function pertaining to producton.

Production Engineer.—The executive officer in an engineering works responsible for the technical side of production from the issue of the design by the drawing office to the delivery of the finished product to the despatch department, usually supervising the work of the progress, planning, and jig and tool departments.

THE MACHINING OF STAINLESS STEEL.

Paper presented to the Institution, London Section, 7th January, 1931, by R. Waddell and F. Worton.

THE description "stainless steel" covers a whole family of alloys, constantly growing in number, and showing wide divergencies in composition and properties. The common link—or family feature—which binds them all together, is that they all contain a high percentage of chromium, broadly speaking, upwards of ten per cent. The two parents of this family are Brearley in England and Strauss, of Krupp A.G., in Germany. The Brearley patents cover a range of steels depending on chromium alone as the corrosion-resisting alloy, whilst the Strauss (Krupp) patents include high percentages of nickel in addition to chromium. But with the growth of the family, the sharp distinction between the two types has become blurred, and steels intermediate between the two main types, or having additional alloying elements, have been produced to meet special requirements.

This paper, however, is not a treatise on stainless steel, but on the machining of stainless steel, and for this purpose a very simple classification will suffice.

Brearley steels: Symbol M (martensitic).

The steels in this group are all more or less hardenable by some form of heat treatment, and are magnetic. They may be usefully sub-divided into three groups.

M (1): Steels with .15 to .35 per cent. carbon and 11 to 14 per cent. chromium.

This is the cheapest type of stainless steel on the market, and has the balancing disadvantage of the lowest resistance to general corrosion. For a great many purposes this resistance is adequate, and as the steels can be hardened to well upwards of 100 tons MS. or tempered back to 45 tons MS., they are useful for a great variety of purposes, such as cutlery, edge tools, high temperature valves for internal combustion engines, valves and seats for dry and superheated steam, parts of machines, and so forth. They should not be used in wet contact with non-ferrous metals or packing, or in sea water or acids, except nitric.

M (2): Steels with less than .15 per cent. carbon and 13 to 16 per cent. chromium.

These steels are softer than those in group M (1), more expensive and more resistant to general corrosion. Some of them will harden to about 70 tons MS., and some will temper back to about 30 tons MS. They are used for turbine blading, sheet metal articles, screws and bolts, and are probably the most hopeful materials for tubes to be operated at high temperatures, as in superheaters.

M (3): Steels with less than .2 per cent. carbon, 16 to 20 per cent. chromium, and 1.5 to 2.5 per cent. nickel.

Steels in this group are slightly harder than those of group M (2) but softer than those of group M (1). Their tempering range is much narrower than either of the preceding, and may be taken for the group as lying between 40 and 70 tons MS. These steels, due to their higher chromium content, are more resistant to general corrosion than M (1) or M (2) and, save in very exceptional cases, will remain unattacked in sea water even in contact with non-ferrous metals or packing. In this respect they are only slightly inferior to the steels in the next—the austenitic—group. The M (3) steels are used for pump spindles, marine machinery parts, valve spindles in packed glands, screws and bolts, wire wheel spokes, and so forth.

Strauss (Krupp) steels: Symbol A (austenitic).

The steels in this group are none of them hardenable by heat treatment, but are to a very noticeable and inconvenient extent, hardenable by cold work. They are all, except in the work-hardened state, non-magnetic. In marked contrast to the martensitic steels, they have a very low elastic range or yield point in their normal state (i.e., not work-hardened).

Steels in this group are more highly resistant to general corrosion than those in the M groups, and some special variants have been developed to withstand attack from even sulphuric acid. In consequence, they have a wide application for chemical plant, cooking utensils, out-door fittings such as shop fronts, tubes for many purposes, and because of their high ductility, pressed metal work of all sorts.

The salient properties of the different steels being thus briefly stated, it is possible to examine the machining difficulties peculiar to each, and to suggest means of overcoming them. But it is proper to preface this examination by a general statement that, in the present state of the steel maker's art, all stainless steels are more difficult to machine than the mild steels and brass which have been the *corpus vilae* of the machinists' operations in the past.

Warpage.

One of the most annoying phenomena in machining slender objects to fine limits of precision is distortion, or change of shape of the machined object, which sometimes occurs instantaneously as the machining proceeds and sometimes, more deliberately, after the machining is complete. The warpage is indeed sometimes delayed until the part is assembled and put to work in an engine or machine, at which stage the consequences may be very serious.

Warpage is caused either by the release, on machining, of internal stress locked up in the material being machined, or by the setting up, through rash machining, of differential stresses in the material.

In both cases a change of form must take place to permit the altered stresses to take up a new equilibrium.

Dealing with the first case, that of internal stress locked up in the material presented to the machine, the prime cause is usually either *cold work* or *hardening* (*heat treatment*) *stresses*. Internal stresses due to cold-rolling or cold-drawing through a die can usually be shaken out in steels other than the austenitic stainless steels, by tempering at some temperature exceeding 550° C. and, where this tempering is admissible, it is the simplest palliative. If, for any reason (e.g., the risk of scaling or loss of induced hardness) it is not admissible, a good deal can be done by prolonged heating at low temperatures, say by boiling at 100° C. and, where the trouble is acute, the remedy may have to be applied at several stages of the machining operations. For less acute cases, a simple period of rest between successive cuts over the surface will often prove effective. But clearly in such cases the machining must not be completed in one cut, as it is on the first cut that warpage will generally occur.

Internal stresses locked up by hardening (heat treatment) are to be expected and guarded against in nearly all alloy steels of high tensile strength, and the stainless steels of the M group fall in this category.

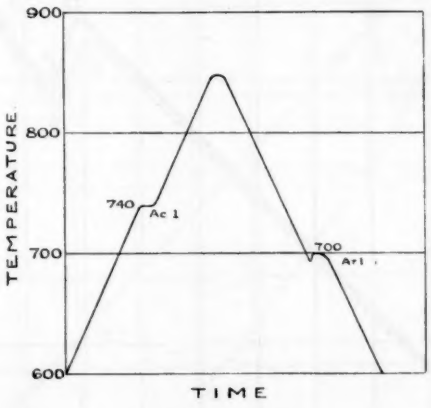


FIG. 1.

HEATING AND COOLING CURVE OF 0.9 PER CENT. CARBON STEEL.

Fig. 1 shows the ordinary thermal curve of the heating up and cooling down of steel. The part to the left of the apex is the heating curve, the part to the right of the apex the cooling curve. On the

particular curve shown in the figure, it will be seen that there is a very marked kink in the curve at points Ac1 and Ar1. These are respectively the calescence and recalescence points, and occur at the temperatures where the carbides go into solid solution on heating, or fall out of solution on cooling. The kinks in the curve indicate that some kind of internal convulsion accompanies this change of chemical state, and the convulsion is in fact a change in volume. Volumetric changes frequently occur in nature with change of state, as for example, in water, which expands on freezing and expands enormously on boiling into steam.

Now this volumetric change on cooling may or may not set up serious internal stresses in an object, according to the conditions of temperature and synchronism at which it occurs. If it occurs

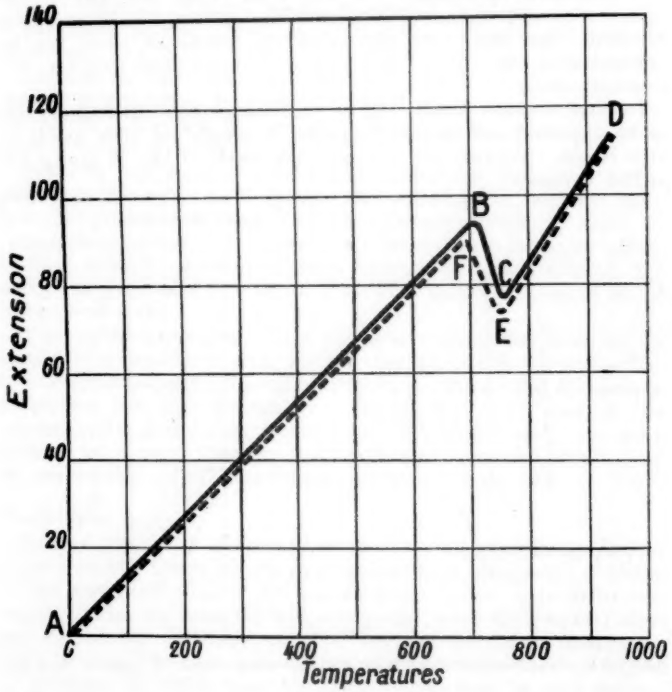


FIG. 2.

CHANGE IN LENGTH OF STEEL BAR DURING HEATING AND SLOW COOLING.

at a high temperature, at which the material is plastic, the piece being hardened can expand and contract freely, and so pass through the change without residual stress. But if it occurs at a low temperature, at which the material is hard and elastic, no plastic deformation is possible, and great internal stresses are set up. These conditions are still further aggravated when the change does not occur simultaneously throughout the mass of the piece being hardened. This is more likely to occur with steels which must be hardened by quenching in water or oil than with air-hardening steels, and more likely with massive than with small objects.

Fig. 2 shows a heating and cooling curve of slow time rate, the co-ordinates being expansion and temperature. It will be seen that the volumetric changes of heating and cooling occur close together at temperatures of 740° C. and 700° C. respectively.

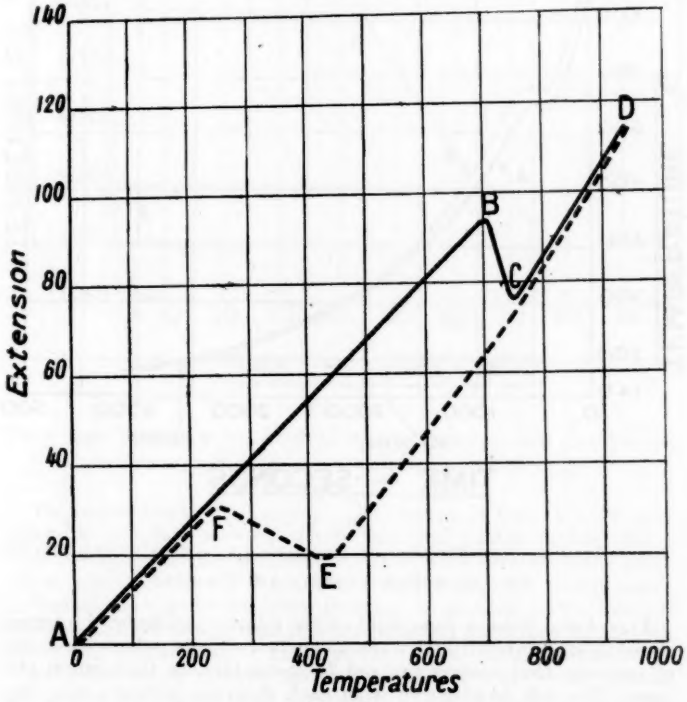


FIG. 3.

CHANGE IN LENGTH OF STEEL BAR ON HEATING AND RAPID COOLING.

Fig. 3 is the curve for the same steel but with a quick time rate (corresponding to hardening conditions) and a comparison with Fig. 2 shows that the cooling change has been shifted to a much lower temperature (250° C.) and the amount of expansion greatly increased, simply by accelerating the rate of cooling. Fig. 2 might reflect the conditions of annealing and Fig. 3 those of hardening. Steel at 700° C. is relatively soft and plastic, but at 250° C. it is hard and elastic. Manifestly then, the cooling change in Fig. 3 being greater in amount than that in Fig. 2, and happening in a much less accommodating medium, must be productive of far greater resultant stresses. Fig. 3 may be taken as typical of the air-hardening of all the martensitic stainless steels.

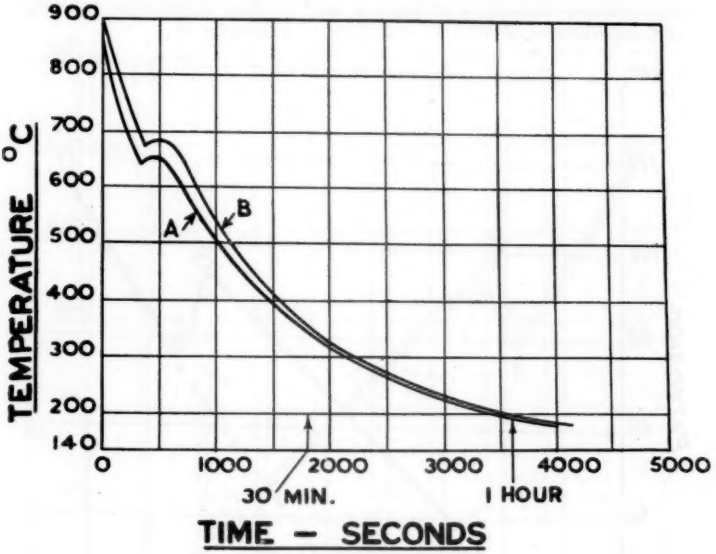


Fig. 4.

Time-temperature Curves of Surface (A) and Centre (B) of Two-inch Bar during Air Cooling.

Figs. 4 and 5 throw some light on the relative incidence of internal stress in air-hardened and water-quenched objects, where these are of such size that cooling can not be instantaneous throughout the mass. The left hand curve A in each diagram portrays the conditions obtaining at the outer surface, while the right hand curve B shows the conditions at the centre. The curves shown deal with

material about two inches in diameter, and are drawn with co-ordinates of temperature and time.

The air-hardening diagram, Fig. 4, shows that the time-lag (in reaching any given temperature) between the surface and the centre, is not great, and that the volumetric change takes place in both positions at about the same temperature.

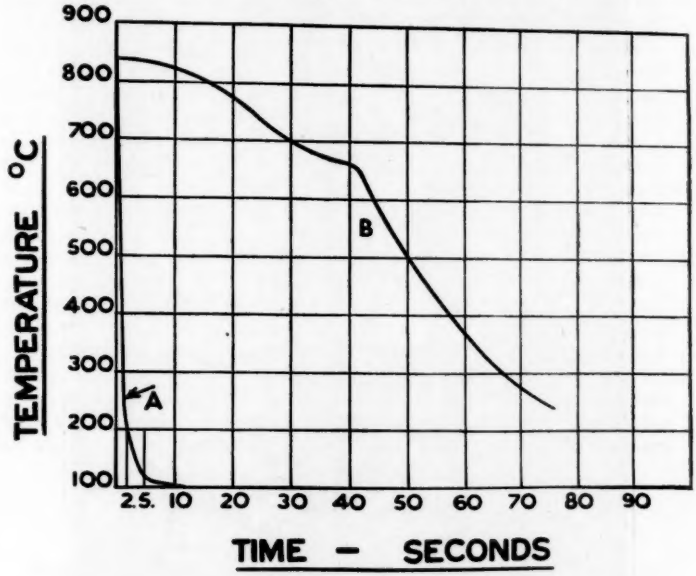


FIG. 5.

TIME AND TEMPERATURE CURVES OF SURFACE (A) AND CENTRE (B) OF TWO-INCH BAR WHEN QUENCHED IN WATER.

The water-hardening diagram, per contra, reveals a very considerable time-lag between the surface and centre curves, and a wide divergence in the temperatures at which the volumetric change takes place. Both of these, the time-lag and the temperature difference, operate in the same direction, to produce severe internal stresses, and the trouble becomes progressively more formidable with increasing dimensions, or mass, of the object being hardened.

Such hardening stresses are to a greater or less extent relieved by subsequent tempering, the degree of relief varying with the tempering temperature. Where tempering can be done at 600° C. or upwards, the relief may be complete, but if great hardness is

required in the finished article such high temperatures may not be admissible, and residual stresses must be expected.

FIG. 6.

ROUGH MACHINED SURFACE SHOWING CRACKS PERPENDICULAR TO PATH OF TOOL.

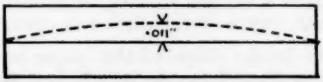
Machining Stresses.

When hard material such as steel is being machined considerable

effort is required, as is proved by the heat generated in the work, the chips, and the cutting tool. The work put into the removal of the cuttings leaves the tooled surface more or less distorted, as shown in Fig. 6. and in consequence, in a state of stress.

The distortion and stress are greatest where the cuts are heavy, and least where the cuts are fine. They are also greater where the cutting tool is blunt, and less where the cutting tool is sharp. From this it follows that an object rough-machined with heavy cuts will be stressed all over its surface, and the odds are against these stresses remaining in exact equilibrium without some change of form. The odds are vastly increased if the cut varies in depth from side to side in respect to the axis of symmetry, as happens when a bar rotates eccentrically in a lathe. To demonstrate this, four bars of stainless steel of the group M (1) $1\frac{1}{2}$ inches diameter and 18 inches long were taken, air hardened 950° C. and tempered 600° C., from which temperature they were again air cooled. These were chosen as the optimum heat treatment conditions for ensuring freedom from hardening stresses. The bars were then machined dead straight with very fine cuts, finished by grinding, to ensure freedom from machining stresses.

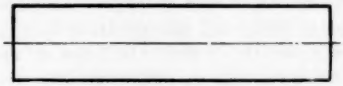
Two of these bars were then off-centred one-eighth inch, and one-quarter inch was removed at one cut from the diameter, which owing to the eccentricity of the bar gave a depth of cut of a quarter of an inch at one side and zero at the other. The remaining two bars were correctly centred, and also reduced in diameter a quarter of an inch with one cut. Fig. 7 shows the amount of warpage



DOTTED LINE SHOWS WARPAGE OF BAR AFTER REDUCING $\frac{1}{4}$" IN DIA. BY ECCENTRIC CUT

FIG. 7.

resulting in the two specimens eccentrically turned, and Fig. 8 shows that no warpage developed in the two concentrically turned.



BAR STRAIGHT AFTER REDUCING $\frac{1}{4}$" IN DIA. BY CONCENTRIC CUT

FIG. 8.

A further point in favour of fine finishing cuts, where stainless steels are being machined, is that distorted surfaces greatly weaken the resistance of the steels to corrosion.

The distortion of the surface material renders it electro-positive to the undistorted material just below the surface, so that in the presence of any electrolyte (e.g., water) a galvanic couple is set up, and selective corrosion begins. This accounts for the insistence on highly-polished surfaces on stainless articles, so often misconstrued and misunderstood. There is no particular virtue in the polished surface *per se*, but a polished surface can only be produced by very fine tooling, smooth file and emery cloth, or with a fine grinding wheel, and thus inhibits rough machining and distorted surfaces. The evil effects of rough machined surfaces as lowering resistance to corrosion, are most marked in the lower chromium steels, type M (1), and least marked in the higher chromium and chromium-nickel steels M (3) and (A). But whichever type of stainless steel is being machined, it is the part of wisdom to aim at the production of an undistorted surface with the highest finish economically permissible.

Before leaving this section one other peculiarity of all stainless steels must be mentioned. This is the tendency of all the materials in the (M) and (A) groups to seize or stick in sliding contact with each other. The seizing of metals upon each other is no new thing in the history of engineering, and it was common practice in a past generation to put wrought iron nuts on mild steel bolts, in the hope of minimising the trouble. With stainless steels, however, the seizing is much more acute, and will occur at extraordinarily low bearing pressures. It is therefore a safe general rule in designing machines, to avoid rubbing contacts of stainless on stainless wherever possible, and as a typical example screw-down valves should be preferred to gate valves if the choice is open.

It is not possible in the scope of this paper to deal with all the instances of seizure that have occurred, but screw threads and nuts should be particularly mentioned. It is desirable in the case of threads one inch Whitworth and over to employ a slightly easier fit when a stainless nut is screwed upon a stainless thread, than is customary with mild steel or other commonly used materials. Further, it is desirable that both the screw and the nut should be finished as far as the flanks of the threads are concerned, with the highest possible accuracy and surface.

Where seizure is incipient, the greatest care should be taken in freeing the nut upon the screw. If force is applied at the very outset, it is almost certain to aggravate the seizure and make it impossible to release. Nuts should therefore be run down by hand very cautiously, so that any tendency to stick can be checked before it becomes a major seizure.

A summary of conclusions of the points so far dealt with may usefully be inserted here.

1.—Cold-work stresses in ordinary carbon and alloy steels and in the martensitic stainless steels, may be reduced by tempering 550/600° C., and to a less extent by prolonged tempering at lower temperatures.

2.—Hardening stresses are least in the air-hardening steels, greatest in the water-hardening, with the oil-hardening lying somewhere between. Where warpage must be guarded against an air-hardening steel should be chosen if a suitable one can be found.

3.—Hardening stresses can be reduced or removed by tempering.

4.—Machining stresses can be reduced by careful centring, by the use of light cuts and sharp cutting tools, and by periods of rest between cuts. Drastic high speed machining with heavy duty machines and special tools holds out alluring prospects in saving labour costs, but there is an inevitable price in warpage to be paid for these savings.

PART II.

The Cold-work Hardening of Austenitic Steels (Group A).

In the general classification at the beginning of this paper, it was stated that the chromium-nickel (A) steels were hardenable by cold work. This, of course, is true of nearly all metals, but in the case of these stainless steels the hardening is so rapid and of such intensity as to create most formidable machining and fabricating difficulties.

Fig. 9 gives the curves of work-hardening rates for four materials, mild steel, stainless iron M (2), nickel silver, and "Anka" stainless steel of 15 per cent. chromium 11 per cent. nickel (Group A).

The curves are plotted with co-ordinates of Brinell hardness and percentage of cold work. This latter is based on the progressive shortening by load of short cylinders of the various materials. In assessing the relative "cussedness" of these materials from a work-hardening point of view, it is the slope of the curve that matters, not its absolute height above the abscissa line. It will be seen that the "Anka" curve is far steeper than any of the others. In stainless steels of the austenitic group, great divergencies in the rate of work-hardening are found, the metastable alloys hardening much more rapidly than the stable. Broadly, the work hardening rate is inversely proportional to the nickel content, being greatest with the low nickel steels and least with the high nickel steels; 15 per cent. Chromium 11 per cent. Nickel steel hardens very noticeably less than 18 per cent. Chromium eight per cent. Nickel.

Fig. 10. Expresses the same facts in a form more directly informative to the machinist, the co-ordinates being amount of deformation and load required to produce it.

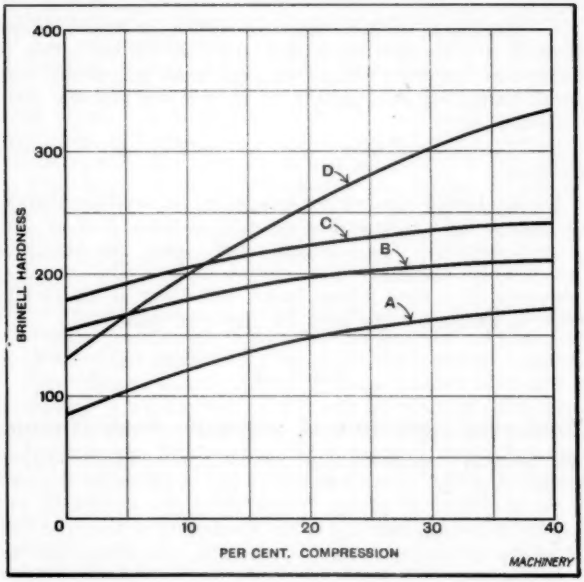


FIG. 9.

RATES OF WORK-HARDENING OF VARIOUS METALS. A—NICKEL SILVER. B—MILD STEEL. C—STAINLESS IRON. D—ANKA STAINLESS STEEL, FIFTEEN PER CENT. CHROMIUM, ELEVEN PER CENT. NICKEL.

Let us now examine the practical bearing of this work-hardening property on machining operation, by an example from the earlier history of the fabrication of large chemical plant. Some large plates of austenitic stainless steel had to be assembled in the form of rivetted and caulked tanks, and the first operation was the planing of a caulking edge. To minimise work (so the fabricator fondly thought) the smallest possible cut was taken, so as barely to remove the high places in the slightly undulating sheared edge. At the bottom of the undulations, no material was removed, and the planing tool simply rubbed over the surface, slightly compressing it. On the next cut, the parts so rubbed proved so hard as to be wholly unmachinable, and the plates were sent back to the steel

maker with a report that they had mysterious "nuggets" or "bones" in them. The plates were re-softened by heating to 1,100° C. and quenching, and the machinists enjoined to take a single cut of such depth as to remove material over the whole length at one cut, and avoid the "rubbing."

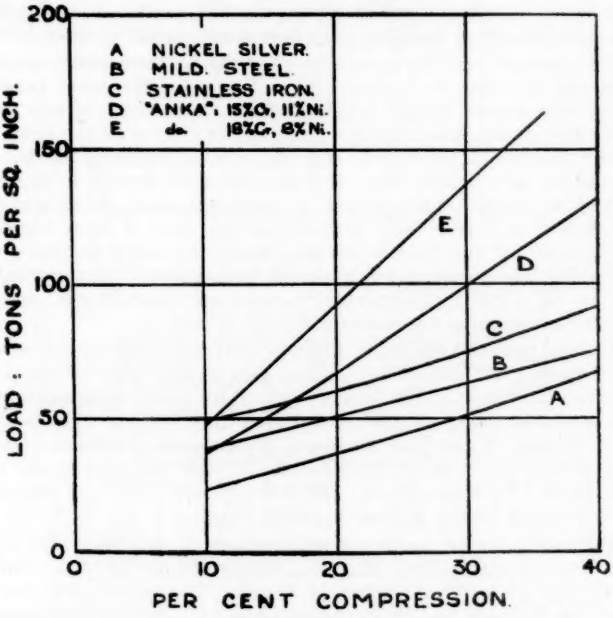


FIG. 10.

LOADS NECESSARY TO COMPRESS VARIOUS METALS.

Next, the plates were drilled for rivets, and the boilermaker centre punched before drilling with a heavy sledge hammer. When the drill was put into the punch-hole, it refused altogether to cut, and the same complaint was repeated. And finally, these difficulties being surmounted, the tanks were rivetted up with rather open joints, and caulking commenced. Before the joint was nearly closed, the caulking edge had got so hard that no tool would touch it, by which time the boilermakers were ready to abandon the job in despair.

There is no need to pursue this harrowing tale further, the part already told providing all the awful warnings necessary. The failure

of each operation, planing, drilling and caulking, was due to one single cause, work-hardening. That part of the plate edge which was rubbed over by the planing tool without cutting, became hard, and refused the tool on the next cut. The heavy centre-punching which preceded the drilling, so hardened the plate over the whole punch-impression, that it refused the drill. And the rivetted joint, not being an almost perfect fit as rivetted, hardened so much in the early stages of caulking that it was impossible to close it.

This property of the austenitic steels being understood, a great deal can be done to mitigate its evil effects. Wherever possible a cut once started should be completed without check of any kind, due either to the tool coming in and out of cut, or to the stoppage of the machine in the middle of a cut. Centre-punching for drilling should be very lightly done, and the drill once started in the hole should be pushed through with a continuous feed. It should not be allowed to revolve idly without cutting, since if these blunders are committed the hole is almost certain thereafter to prove undrillable. Boilermakers' joints should be assembled for rivetting so far as to make metal-to-metal contact all their length, and so require a minimum of caulking.

Drilling is one of the most difficult operations with the (A) steels, since there must always be a small area at the point of the drill, between the flutes, which does not cut. With drills of large diameter the work-hardening of this central area does not prevent the drill from cutting, if a sufficiently heavy pressure be maintained on it. But with drills of small diameter the trouble becomes acute, and it is practically impossible to drill holes of, say, 1/32-inch diameter of any depth in the austenitic steels.

Tapping holes is another fruitful cause of trouble. The chips can never escape freely from a tap, and by the nature of the tool, a great deal of rubbing contact is set up. The drilled hole should therefore be made slightly over-size if it is to be successfully tapped. Particulars of tapping holes found successful in practice are shown in the appendices at the end of this paper.

Wherever work-hardening has taken place, and it is desired to remove it, the only remedy is to re-heat the object to some temperature between 1,000° C. and 1,150° C., depending on the composition of the steel, and from that temperature quench in cold water. Very small parts (less than a quarter of an inch in diameter or thickness) may sometimes be air-cooled, but water quenching is the safer. Slow cooling leaves such steels in a very dangerous state metallurgically, liable to serious inter-granular corrosion. Partial or local heating has the same bad effect, as also heating to any temperature below 1,000° C.

The authors have felt some diffidence in appearing before a scientific audience with a paper on this particular subject, because

the mass production or production machining of stainless steels is still in its infancy, and the amount of data available is distinctly limited. Further, the authors' own personal experience, whilst probably wide in respect of the number of problems tackled and the variety of steels worked upon, has not been of the mass production kind.

They have, in conclusion, to thank the Directors of Brown, Bayley's Steel Works, Ltd. for permission to publish such data as is embodied in this paper.

PART III.

Various Tables and Data.

Turning.

When turning stainless steels, it is advisable to increase the top

Table I.

Turning Speeds and Feeds for Stainless Steels.

	"A" Steels			"M1" & "M3" Steels			"M2" Steels.		
	Depth of Cut	Feed per Rev	Speed F.P.M.	Depth of Cut	Feed per Rev	Speed F.P.M.	Depth of Cut	Feed per Rev	Speed F.P.M.
Up to 1" dia.	1/32	·03	50	1/32	·03	55	1/32	·03	60
	1/16	·025	45	1/16	·025	50	1/16	·025	55
	3/32	·020	40	3/32	·020	45	3/32	·020	50
1 1/8 to 2" dia.	1/32	·04	50	1/32	·04	55	1/32	·04	60
	1/16	·03	45	1/16	·03	50	1/16	·03	55
	3/32	·03	40	3/32	·03	45	3/32	·03	50
2 1/8 to 3 dia.	1/32	·05	50	1/32	·05	55	1/32	·05	60
	1/16	·04	45	1/16	·04	50	1/16	·04	55
	3/32	·03	40	3/32	·03	45	3/32	·03	50
	1/8	·03	40	1/8	·03	40	1/8	·03	45
3 1/8 dia. to 4 dia.	1/32	·06	50	1/32	·06	55	1/32	·06	60
	1/16	·05	45	1/16	·05	50	1/16	·05	55
	3/32	·05	40	3/32	·05	45	3/32	·05	50
	1/8	·05	40	1/8	·05	40	1/8	·05	45

To get maximum production maintain given speeds and feeds and increase depth of cut as much as work will allow. In some cases it may pay to reduce feed and increase depth of cut.

rake of the tool from 2° to 5° above standard used on, say, steel of 40 tons tensile strength. The best results cannot be obtained if the tool is not rigid. It is therefore wise to have the tool supported as near the cutting point as possible, and the tool should not be allowed to rub on the job without cutting. A good cutting compound is an asset.

Table 1 deals with feeds and speeds for lathe work, based on light cuts as recommended in the body of the paper. In amplification of Table 1, where for any reason it is impossible to finish an object by grinding, it may be turned with very fine cuts at feeds of about 120-160 per inch, at speeds of 80-100 ft. per minute. The subsequent mirror-polish of such a surface is easily achieved by file and emery cloth.

Milling.

Speeds of 50 feet per minute on a cut of a quarter of an inch deep by 1/32 inch traverse, can be run on M (1) stainless steels. On M (2) stainless steels the speed may be increased to 60 feet. (A) stainless steels call for a reduction to 40-45 feet with a feed of about .016 on a quarter of an inch deep cut. The cutter should be ground with a clearance angle of 7° to 10° and kept sharp. It is important that the cutter runs true and does not throw all the work on a few of the teeth. Use a good cutting compound. Rigidity of tool and cutter is again important.

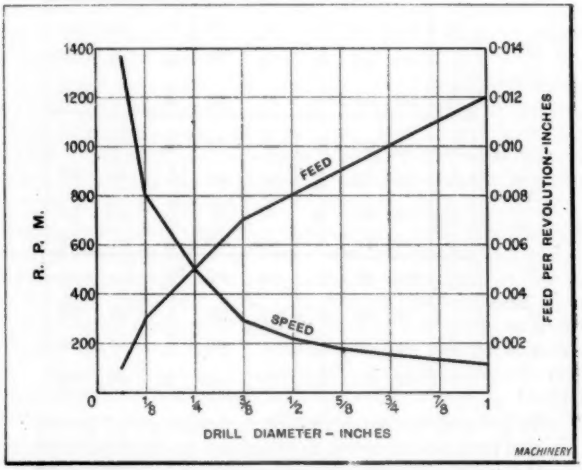


FIG. 11.

Cold Sawing.

Use high speed steel hack saw blades at about 60-70 cutting strokes per minute on M (1) stainless steel. On A steels 45 strokes per minute will be found satisfactory. The blade must not rub on the return stroke.

Drilling and Tapping "A" Steels.

Always use a high speed steel twist drill. The cutting lips of the drill should be ground with more back clearance than standard (16° is satisfactory), also grind the included angle of the cutting edges to 115° inclusive angle as against the standard 118° (see Fig. 11) and thin the drill point. The short spiral flute drill as used for drilling copper and aluminium ground as above, gives good results.

It is desirable that the drills used should be as short as possible, and when a drill chuck is used, the drill should be gripped as low down as possible in the chuck, reducing any spring to the minimum. Eliminate any play in drill spindle. When drilling any austenitic steel care should be taken to ensure that the job is very lightly centre punched. *Feed the drill straight into the work, not allowing it to dwell, as this will cause work-hardening.* A good cutting lubricant should be used.

Tapping of "A" Steels.

Tapping holes should be larger than standard, as referred to in the body of the paper. Table II gives dimensions found useful in practice.

TABLE II.

TAPPING OF "A" STEELS.

Tap Size.		Drill Size.	
1/4"	Whitworth.	13/64"	dia.
3/8"	,,	5/16"	,,
1/2"	,,	27/64"	,,
5/8"	,,	35/64"	,,
3/4"	,,	21/32"	,,
7/8"	,,	49/64"	,,
1"	,,	7/8"	,,

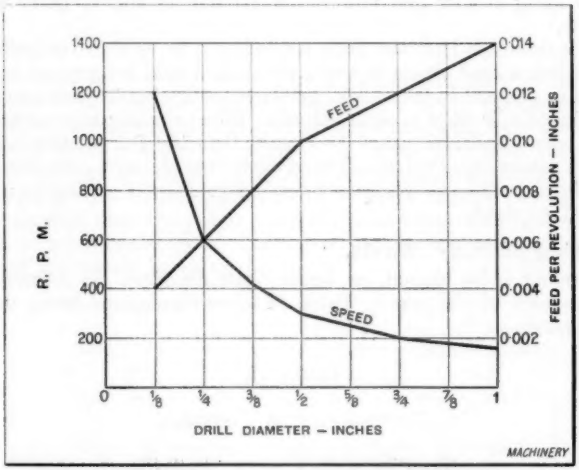
For hand tapping four-fluted ground-thread taps give best results, A little tallow on the tap is helpful. These steels will machine-tap at about 10-12 feet per minute when it is possible to employ a *tap with a long lead.* Machine-tapping on blind holes is not satisfactory.

When die-screwing 10-12 feet per minute will give fairly good results, using dies with 20° throat angle and about 12° of top rake. Dies must be kept sharp.

Drilling and Tapping " M " Stainless Steels.

No difficulties will be encountered when drilling these materials, providing a good high speed drill is used and kept sharp. For hand tapping four-fluted ground-thread taps give best results. This material does not machine-tap well. When die-screwing, 10-12 feet per minute will give fairly good results, using dies with a 20° throat angle and about 12° of top rake. Dies must be kept sharp.

Fig. 12 is the drilling chart for " M " steels.



For M. (2) steels increase revolutions per minute 10%.

FIG. 12.

(*Further illustrations were then shown of a difficult job of drilling and tapping in M* (1) *steel, and of a large governor needle-valve for a Pelton wheel. Acknowledgments are made to " Machinery " regarding three of the illustrations used above*).

Discussion

MR. E. J. H. JONES, in expressing appreciation of the paper, said that for the most part it contained plain statements of fact, which engineers could appreciate, because they were not always so fortunately served. Nevertheless, he was a little disappointed

that the paper did not contain more details concerning the actual machining of specific parts, particularly those parts with regard to which controversial statements were afloat, one such part being the radiator cowl. One heard that in some works radiator cowls were being made successfully in stainless steel, whereas other works had not obtained sufficiently good results to justify the adoption of stainless steel. He asked whether this was due to any difficulty in connection with deep pressing of the austenitic steel, or whether it was because the cost was—as he believed—100 per cent. more for stainless steel than for nickel chromium plated or brass chromium plated. Also, in view of the possibilities of the use of stainless steels for tanks and like articles, he asked for information as to the welding of these materials. Owing to the co-efficient of expansion of these materials being quite 50 per cent. greater than that of ordinary mild steel, there was, besides the difficulty of welding satisfactorily, danger of severe warping. The electric process was understood to be the better, but the oxy-acetylene process could be used, provided that time was taken over the operation and the welder refrained from using the bigger nozzles and higher pressures used for ordinary mild steel. He believed it was recognised that much less heat was required for the austenitic chromium steels, because they did not conduct the heat away so rapidly as did the ordinary mild steels.

Mr. Jones exhibited a specimen of a pump spindle as an example of what could be done with stainless steels. The steel used was one of the martensitic group (which group contains from 0.25 to 0.35 per cent. carbon and from 11 to 14 per cent. chromium), and the specimen was machined from heat-treated bar to approximately 55 tons tensile maximum stress. There were ten diameters and nine lengths. Each of these diameters had been reduced from the bar in one cut, the greatest depth of cut being over half an inch. The time for the whole piece was thirty minutes for the long end and ten minutes for the short end. The screw thread, though not perfect, was quite a good job and, contrary to the authors' recommendations, lipped or "S" type dies had been found to give the best result. The speeds and feeds used were approximately from forty to fifty feet per minute and from 100 to 155 cuts per inch. The tendency to pick up on this metal was quite noticeable on this part, particularly on those diameters which had been roller boxed. The pieces had then to be straightened, and it was found usually that machining stresses had caused deflection of approximately two mm. These diameters were then finished by grinding, the grit and grade of wheel used being 40 BO. Aloxite. It had never been found after the grinding operation that this part had moved out of truth.

In machining any metals or any substance certain rules had to be observed if success were to be attained. His experience of stainless steels was confined to the martensitic group, and difficulty had

been experienced at first, but no trouble is experienced at present. When the machining of stainless steel was first undertaken at his works the material was purchased in the annealed condition, and it was subsequently heat treated before final grinding. The part being manufactured then was also a pump spindle, but it had an internal screwed hole approximately three inches in length and half an inch in diameter, and it was found extremely difficult to produce this hole and thread. After experimenting, however, it was found that when the material was heat treated before this operation it was possible to drill and thread the hole quite satisfactorily. Therefore, it had become the practice to buy the material in the heat-treated condition to a maximum stress of approximately from 55 to 60 tons tensile.

He asked for information as to the occurrence of corrosive spots on stainless steel, due to the segregation of chromium, for he had heard that such spots did occur, though he had not seen actual examples.

The martensitic group of stainless steels was not rustless for ever, but the amount of corrosion over a commercial period of life depended entirely upon the finish originally applied to the article. The rate of wear on automobile parts was often faster than the rate at which corrosion took place, so that, although stainless steels had helped considerably in regard to certain parts, the stainless quality was perhaps not so important there as in other branches of engineering.

MR. WADDELL, replying, said he imagined that the difficulties arising in connection with radiator cowls were mainly deep pressing difficulties associated with work-hardening. Welding troubles were due, in the first place, to imperfect knowledge of what happened when welding with an oxy-acetylene flame. If stainless steel were welded with a highly oxidising or highly reducing flame, trouble would result, therefore, one should aim to use a flame as nearly as possible neutral. The weld should be made at one blow, and should never be gone over twice, because in the latter event it would crack and would be ruined. Further, in the austenitic steels, welding would result in a very serious corrosive defect, called "weld decay" unless subsequently re-heated. Although the weld itself would be heated to a temperature far in excess of 800° C., some part of the steel adjacent to the weld must have been re-heated, during welding, to within the range from 400° to 800° C. Within that range, the carbides in solution would fall out of solution in a network around the crystal boundaries, and that network was attacked very readily by corrosion. That part of the material, therefore, would disintegrate in an appalling way, unless the material were re-heated, after welding, to a temperature exceeding 1,000° C, and quenched in water.

The improvement in machining properties resulting from heat treatment was quite a commonplace even with ordinary steels; the most free-cutting steels were in general rather harder than the mild steels. The hardened and tempered material referred to by Mr. Jones, being harder, was less liable to drag on the tool than was the annealed material previously used.

The " corrosion spots " mentioned were probably slag inclusions. If stainless steel contained any form of non-metallic inclusions, it had two different kinds of material lying side by side, and in the presence of some corrosive medium there resulted a galvanic couple and selective corrosion of one or the other.

MR. WORTON, who also replied, said that the sample of a pump spindle produced by Mr. Jones served to emphasise further the point made in the paper that, in order to achieve success, one should use fine feeds and increase the speed as much as possible. With regard to grinding, he said that his company were not mass production experts, but steelmakers, and could not go to the trouble of changing wheels for every odd job, but they had found that a 24-combination M was a good general-purpose wheel, and a 60-L wheel was very good for finishing.

MR. POWELL asked if a stainless steel ball race could be hardened sufficiently to enable it to withstand the stresses imposed on ball races in modern high-speed machinery. In his own experiments with high-speed machinery he was using ball races made of non-corrosive material by one of the most prominent ball race manufacturers, and his experience was that their life was not a quarter as long as that of the ordinary carbon steel ball races.

MR. WADDELL said the answer was in the negative; the property of resistance to corrosion could be bought only by some sacrifice of hardness. However much stainless steel was hardened, it was never file-hard—it could always be filed. Stainless steel used for ball races should have the lowest possible chromium content and should contain a great deal of carbon, and such ball races should be loaded to perhaps only a quarter the load applied to ball races in automobile practice.

MR. C. C. FERGUSON was rather surprised that the authors had not referred to the use of stainless steels for plate work as, for instance, in the building of ships and other large structures. If it were not used largely for such purposes, was it because the cold drawing that was necessary detracted from its value, or because the punching operations weakened it?

MR. WADDELL said that reference to operations such as boiler making, shipbuilding, etc., had been omitted from the paper because it was assumed that the members of the Institution were interested mainly in machine shop production, but he apologised for the

omission. Stainless steel, he continued, had been used very largely for plate work ; during the last few years a greater tonnage had been absorbed in the making of large rivetted structures such as tanks, particularly in chemical plant, than in any other direction, and there were no serious fabricating difficulties other than those arising from the work-hardening of the material. Very large nitric acid plants had been constructed in this country and abroad, particularly in America, in the Brearley (martensitic) stainless steels of the softer kind, which were wholly immune from attack by nitric acid. These steels were used because they were cheaper than the Krupp (austenitic) steels, and also because the difficulties of rivetting and caulking were not so acute, as these steels did not work-harden as did the austenitic. Plates thirty feet long, seven or eight feet wide, and seven-eighths inch thick had been used, and fabricated into tanks having diameters as great as thirty feet. He did not think the material would be used in ships, owing to its cost. In connection with cost, he said he had calculated that the total cost involved in the painting of the Forth Bridge since its erection (1883-1890), up to the present time, was equivalent to £1 per ton of steel used. In view of that low cost of painting, there was no possible excuse for building it of stainless steel.

Mr. Sumner asked if the authors had had experience of the use of the new cutting materials other than ordinary high-speed steel as, for instance, Widia.

Mr. Worton replied that they had not used Widia for small work, but they had used it on the bigger bars coming from the mills, and had not achieved success ; the bars were badly shaped, and the conditions, therefore, were not conducive to securing the best results with Widia. It chipped and broke. Any good tool steel would give good results—an 18 per cent. tungsten steel was quite good.

Mr. W. H. Salmon said he believed stainless steel was being used by some firms for moulds used for the moulding of synthetic materials, such as Bakelite, and he asked what were the advantages of its use for that purpose. He also asked if the stainless steel was non-abrasive, and whether it would hold the heat well as compared with other alloys. Arising out of the authors' references to the liability of stainless steel parts to seize when in sliding contact, he asked if seizure was likely to occur also when two plungers, made of the same stainless steel, came together in a bakelite mould. Further, if it were necessary to use different steels for the plungers and the container, what steel would the authors recommend for the container working with stainless steel plungers, and what should be the finish of the container.

Mr. Waddell agreed that a certain amount of stainless steel was being used in the form of flat and highly polished sheets against

which to mould synthetic materials, he did not know why it was used in preference to ordinary steel. With regard to abrasion, all the stainless steels were much more highly resistant to it than were the ordinary carbon steels, as evidenced by the effort required to grind them; they were more or less in the same class as the manganese steels invented by Sir Robert Hadfield in regard to resistance to abrasion. The thermal conductivity of the Brearley steels was approximately the same as that of the ordinary steels, but the thermal conductivity of the austenitic or Krupp steels was lower; it was more difficult to pump heat through them. In regard to seizure of stainless plungers in moulds for synthetic materials, he assumed that the mould consisted of some kind of cylinder, tube or bush into which the plungers fitted practically tightly, and the plungers were meeting end to end in direct pressure. In that case no harm would result from the meeting of the two plungers, but if both the plungers and the cylinder were of stainless steel, trouble would occur due to the sliding contact between the plungers and the inside of the cylinder. He had been interested in the making of apparatus for producing flat tabloids of compressed powder, the compression being brought about by two plungers in a bush or cylinder. The fit as between plungers and cylinder had to be sufficiently tight to prevent leakage of the powder, and he believed the use of stainless steel was abandoned in view of the probability (it was almost a certainty) of seizure. If some other material were to be used for the cylinder, and if that other material must be steel, he would suggest the use of a case-hardened steel, glass hard to the file. If, however, it were desirable to use a soft material, he suggested a non-ferrous metal of the high nickel bearing type, such as "Platinin," "Magnum Metal" and so forth, which worked fairly well in rubbing contact with stainless steel. The glass hard, case hardened steel, however, would probably be better than anything.

MR. POWELL, confirming the point with regard to seizure resulting from sliding contact between two pieces of stainless steel, said he had been experimenting with a sliding air valve in which it was necessary to use non-corrosive material, preferably a steel. The valve had to be subjected to tests at a pressure of about 200 lbs. per square inch but, owing to the seizure, it was an utter failure in stainless steel.

A SPEAKER, who asked for information in regard to the arc welding of stainless steels with other metals, such as mild steel or boiler plate, said that stainless steel parts had been introduced into electrical apparatus to prevent eddy currents, but considerable difficulty had been experienced in welding the two together to produce an oil-tight joint, working under pressure in some cases.

MR. WADDELL replied that when one welded a stainless steel, containing 12, 14 or 16 per cent. of chromium and possibly a high

percentage of nickel as well, to an ordinary mild steel, obviously, although there was stainless steel on one side of the weld and mild steel on the other, in the weld itself, and for a short distance on either side, there was a metal which was a hybrid between the two. Some part of that hybrid zone would almost certainly consist of intensely air-hardening nickel-chromium or straight chromium steel and, during the cooling down from the welding temperature, that air-hardening part would crack. Therefore, it was extremely difficult to weld the two when the area was considerable. It was easily possible, however, to butt weld seven-eighths inch rods together, one rod being of mild steel and the other of stainless steel; there the mass was small, and the cooling could be effected without setting up intense residual stresses.

MR. POWELL asked what was the best cutting compound for milling stainless steel.

MR. WORTON replied that he used "Simplicit"—a soluble oil—and it gave very good results.

MR. GROOMBRIDGE asked what kind of file should be used on stainless steel for plate work.

MR. WADDELL replied that obviously, if a file were to cut successfully a steel which would work-harden, it must no trub. A very great many of the worst cut files had teeth which in section were very like a screw thread, i.e., both flanks were inclined together. A file for stainless steel should have a positive angle forward of all the teeth, and by means of a small-powered glass one should be able to determine whether a file was suitable or not. In reply to a question as to whether such files were obtainable, he said he believed they were.

MR. FERGUSON asked how plates of stainless steel could be marked out, if one were not allowed to centre punch them.

MR. WADDELL replied that, of course, one could not place a definite prohibition on centre punching, but it should be as small as possible, and one should use a sharp punch and a very light hammer.

A SPEAKER asked what was the best metal to use for the rolling tool for spinning stainless steel, in view of the fact that stainless steel hardened quickly.

MR. WADDELL said he had no experience of the making of spun articles, but from theoretical considerations it would appear that the material of the tool did not matter. The trouble experienced in a spun article was due to the deformation of the sheet and not the bearing of the roller upon it; the greater the depth of the spun article, of course, the greater the deformation.

A SPEAKER asked what was the result of the brazing or soft soldering of stainless steel.

Mr. Waddell replied that the result depended on the type of brazing or soldering mixture used. When a soft solder was used, and where the temperature was low, no evil results need accrue, but in high temperature brazing, such as was applied to turbine blading—it was impossible in that case to braze at temperatures below 800° C.—there was a danger of raising the temperature of the article being brazed to within the hardening range of temperature and rendering the material comparatively brittle. Therefore, if it were necessary to braze a stainless steel article of the chromium type, one should choose a steel having a very low carbon content [of the M (2) group], which did not harden intensely when heated to a high temperature. The austenitic type could not safely be brazed.

A Speaker, who asked for information as to the forging of the various stainless steels and as to whether it was necessary to anneal them after forging, said he had not experienced trouble in "rustless iron" after forging, and it was not necessary to anneal.

Mr. Waddell said that the stainless irons were within the M (2) group—low carbon, high chromium steels. When properly heat treated they possessed good properties, but if one bought a bar in the heat-treated condition and forged one end, the forging would destroy the effect of the heat treatment, and the part of the bar in the neighbourhood of the forged part would have much poorer physical properties than the bar in the original heat-treated condition; the part raised to the actual forging temperature, if not subsequently heat-treated, would be harder than the remainder of the bar. It might not suffer very seriously from the rust-resisting point of view, but it would suffer, the degree of suffering being greater as the carbon content was greater.

The Speaker said that the chromium content of the material he used was about 18 per cent., and the carbon was eliminated as far as possible.

Mr. G. H. Hales commenting upon a reference made by the authors to warpage, giving as example the machining of a stainless steel crankshaft, suggested that the distortion referred to also occurred in high tensile steels other than stainless, and it was probable that in the authors' case the distortion trouble was not due merely to the fact that stainless steel was used, but rather to the method of machining. He assumed from the authors' remarks that the shaft was located between centres in a machine driven from one end only, in which case the tooling pressure would cause undue tortional strain when operating at the greatest distance from the driving support. He referred to tests which had been taken when turning a six-cylinder engine crankshaft. The results of the machining test showed that when the crankshaft webs were turned in a machine driven from one end only, the amount of

material which had to be left on the crank pins to correct warpage was nine mm. Tests taken on another machine driven from both ends showed that it was only necessary to leave an allowance of five mm. on crank pins to correct warpage whilst by using another machine which was driven from both ends and also from the centre, the necessary grinding allowance to correct distortion was only three mm. The same depth of cut and the same feed and speed were used in each case. From the above it would appear necessary for the crank pins to be supported as near as possible to the cutting tool when in operation. He said that no special reference had been made to reaming of stainless steel, and asked for information regarding this operation. Finally, with regard to the tables given concerning the machining of stainless steel, he urged the necessity for stating the exact type of cutting steels the various figures related to, because he had experience of outstanding cases where much better results had been obtained in machining stainless steel than those given in the authors' paper.

MR. WADDELL replied that when referring to the machining of crankshafts the authors had not in mind stainless steel crankshafts; they were referring to the warpage due to drastic cuts and great depth of cut in ordinary alloy steel crankshaf during the war. The fact that the machine was driven from one end only might have been a contributory cause of the distortion in the crankshafts referred to.

MR. WORTON, discussing reaming, said that in the austenitic steels it was impossible to get anything like a decent hole. With regard to tool speeds, the figures in the paper were related to 17 or 18 per cent. tungsten steels, and they were on the low side, but the authors asked the specialists to use their own common sense and to increase the speeds if that were considered necessary.

On the motion of Mr. G. R. Marsh, seconded by Mr. Groombridge, a hearty vote of thanks was accorded the authors for their paper.

THE PRODUCTION ENGINEER AND BUSINESS TRAINING.

By M. P. Dalton, B.E. (N.U.I.), Member.

IT has long been an aphorism that a commercial engineer is a "rara avis." Strangely enough, this applies with great emphasis to the average production engineer, whose whole claim to notice is his mastery of efficiency methods. Too many production engineers are merely tool engineers. Granted that the actual production method is of supreme fascination to him, he must realise that tool engineering is a mere detail in the qualifications required to reach the great rewards which are now open to the efficiency expert. It has been the writer's sad experience to see several first class brains in this profession relegated to the background simply through concentrating on the technical side of the work,and neglecting training which is of the first importance, namely, training in those fields of organisation and efficiency methods which are the foundation of the title production engineer. If a man does not wish to resist the lure of technical research, he should definitely drop the title of production engineer in favour of that of tool designer, or similar style in his specific technical branch. In doing so he is to realise that he forfeits the greater rewards of the efficiency expert.

In view of the laxity in nomenclature amongst technical writers, a few definitions are here necessary, and the definitions given are somewhat at variance with current practice, but unless steps are taken to clarify the meaning of terms, confusion will inevitably arise in production literature.

Tool designer.—One who designs tools.

Production engineer.—One who undertakes to provide an efficient layout for a factory or other industrial undertaking, is an expert tool designer and can design special machines when required ; he is responsible for arranging and teaching new technical methods of working and handling materials.

Efficiency expert, production manager or general manager. Is responsible for organising and controlling the cost system, progress, planning and stores ; he requires the assistance of a workshop accountant and of a general accountant, a chief progress man who must be partly technically trained in the particular trade concerned, but not of necessity an engineer, a planning expert who requires engineering training and a labour training.

The position of works and general manager become synonimous, and differ in degree of authority only with the exception that the general manager alone must control the workshop accountant, as

the latter is a check on the works manager. If all these definitions are accepted, the post of works manager vanishes as the duties are more efficiently performed under the specialised conditions. The aim of this article is to show that the proper sphere of action towards which these, usually termed production engineers should aim, is that of general manager. It is of interest to note that our American colleagues use the term "scientific management" and not "production engineering" thus avoiding the point here discussed.

The position will be more clearly stated if the term "scientific manager" is now used, as introduced many years ago by Taylor, instead of the term production engineer. It may also be noted that most general managers and managing directors at present at the helm of engineering firms are managers with commercial and not engineering training. This is where the so-called production engineer should step in. Most of us have come up against the non-technical manager at some time or other, but that manager is the chief and rightly so, because he has the commercial training which the engineer so often lacks. There was a university in Russia before the war which included an accountancy training in its engineering syllabus and required the undergraduate to hold a position of manager to an engineering firm for a year, before granting a degree. This is the correct line for engineering training for the scientific manager, and it is regrettable that the British universities do not adopt the same procedure.

If an engineer aims at the position of scientific manager, the first requirement is that he should become thoroughly acquainted with cost accounting as applied to the shops. This is the only means that exists of appraising the results, especially when new machines or practices are introduced. Two common examples at once present themselves. (1) A machine is introduced which is more modern than the old one. Does it pay? Not always, sometimes the cost of the new machine is prohibitive or the cost of the tools is excessive. (2) Again, a machine which cost a certain sum and which can be replaced for the same amount, requires repair. Does it pay? The engineer is always inclined to reason thus. "The machine can be repaired for fifty per cent. of the cost of a new one, therefore it will pay to repair it." The cost accountant argues in another manner. "This machine has already cost for three repairs during the last year respectively twenty to sixty per cent. and fifteen per cent. of the original cost; a new machine will not normally require repair for two years, therefore it will not pay to repair this machine except in the case of an emergency." These are typical examples of the change in judgment effected by a knowledge of workshop accounting. Obviously, the decision in each case of alteration and of undertaking must be judged by the accountant or by the manager only, unless the engineer shows himself proficient in cost analysis.

This divergence of judgment due to difference of mental equipment is the root cause of the misunderstandings and ill feeling which so often develop between the commercial and technical sides of a shop organisation.

But if the scientific manager aspires to reach out beyond the technical side of his profession he must add two other lines of knowledge—commercial law and general commercial training in salesmanship and finance. How often does the engineer propose a logically profitable development to the works, only to be met with the reply that finances are not available and here again the engineer too often fails to understand the complexities of commerce which may make a profitable development impossible.

It is a pity that the training and knowledge of up-to-date records which the scientific manager possesses is so rarely applied to the office organisation as distinct from the shop office. Our biggest bugbear is certainly overhead costs arising from sales and commercial staff, yet it is rare that the office records of a well organised manufacturer show any trace of the wonderfully efficient systems of cross indexing and filing by which our technical records have reached such a fine standard of accuracy and speed of reference. A recent case came to the writer's notice where references had to be made to some three hundred orders each day out of a total of over a hundred thousand. Such references, in cumbersome registers, frequently took several hours each. The introduction of the card index reduced the time to a few minutes, thus releasing staff to fill the newly created shop posts of progress men and storekeepers.

The training outlined here merely makes success possible when joined to executive experience—most of our readers will know from experience the difference between planning a scheme and putting it into practice. This experience is not only gained by personal work but even more by visits to other factories and no greater error can be made, by the would-be efficiency expert in any trade, than to confine his interest to shops in his own line of business, yet he usually shows a good-humoured boredom when invited to visit a knitting factory or a bottle works. It is, in the writer's experience, rarely that a visit to a particular non-engineering factory will not solve a problem met in the purely engineering shop. Most of us can remember as a distinct event, the period, early in the late war, when presswork became popular, yet many engineers to-day think they know all about presswork because they have read all the literature available, which, of course, has been written entirely by engineering shopmen, yet there is a huge field of new and sometimes wonderful presswork in factories making buttons, biscuits and jewellery, while any large boot factory will teach something of pressing non-metallic blanks which is not commonly known to the engineer. Does the average press man know when a drop hammer would pay better than the press, and that a sixty-pound

hammer working at one thousand strokes per hour can do more and better work than a hundred-ton press on certain embossing jobs.

One other point of the utmost importance to the efficiency engineer must be noted. The engineering trades are mostly highly competitive, and although production training can only be obtained in the engineering shops at present, the biggest scope for the modern production methods, especially technical methods, lies in the non-engineering shops, and as the machines of such shops have been invented and built, in many cases by people without mechanical training, there is a rich field here for the inventive mind. There appears no more enticing field of work to-day than the introduction of production engineering methods into the textile and similar trades. If the reader does not accept the argument, it is hoped at least that he will visit three non-engineering factories before ignoring the possibilities outlined.